Satellite Based Investigations of Day-of-Week Variation in NO_x Emissions

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Introduction

Urban and regional air quality is strongly affected by NO_x emissions. In order to improve predictive capabilities and guide cost effective regulation we need a better understanding of NO_x sources and sinks. In the state of California, mobile sources account for more than 50% of NO_x emissions. Regulation focusing on passenger vehicles has led to dramatic reductions in total NO_x emissions, while heavy-duty diesel vehicle emissions have not decreased and therefore represent a growing fraction of total NO_x emissions. A pronounced weekend effect, marked by a substantial decrease in measured NO_2 on weekends when compared with measurements on weekdays has been observed in urban areas due to variation in the activity patterns of these two types of vehicles. We examine this weekend effect using observations from the Ozone Monitoring Instrument (OMI). Satellite observations offer complete coverage but have not yet been used extensively in air quality applications. We have developed a high resolution (5 X 5 km^2) average of the OMI observations that permits a detailed view of spatial variations in emissions with day of week. Here, we describe research aimed at:

1) Characterizing the precision and accuracy of OMI data

2) Understanding the sources of NO_x emissions

3) Understanding the trends in those sources

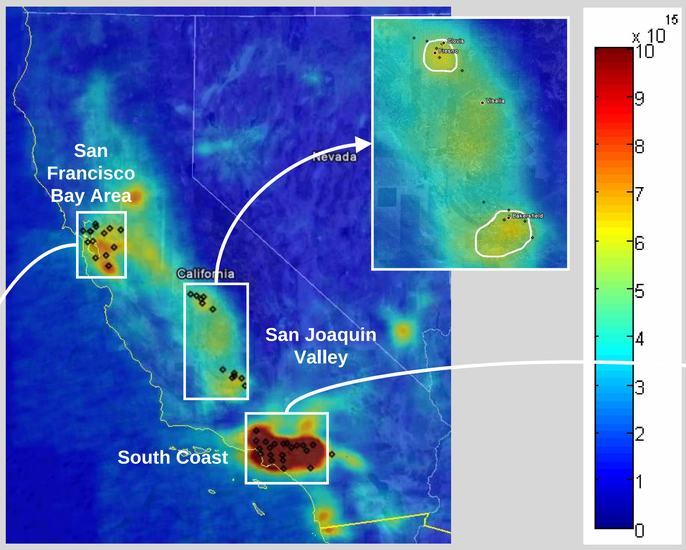

Figure 1. Average tropospheric NO_2 column concentrations (molecules/cm^2) from the Ozone Monitoring Instrument for Jun-Aug 2005-2008. White boxes highlight regions of focus in this study. Black diamonds show locations of CARB ground based monitors used in this analysis. Inset shows a closer view of the San Joaquin Valley with white outlines defining areas from which OMI measurements were taken for analysis for Figures 5-7.

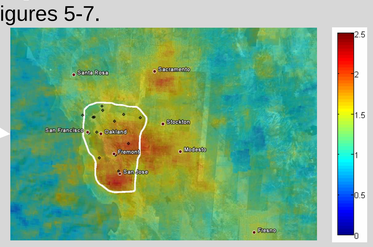

Figure 2. Ratio of weekday to weekend NO_2 columns from OMI in the San Francisco Bay region. Densely populated areas show a ratio greater than one due primarily to increased diesel emissions on weekdays relative to weekends. White outline and black diamonds as in Figure 1.

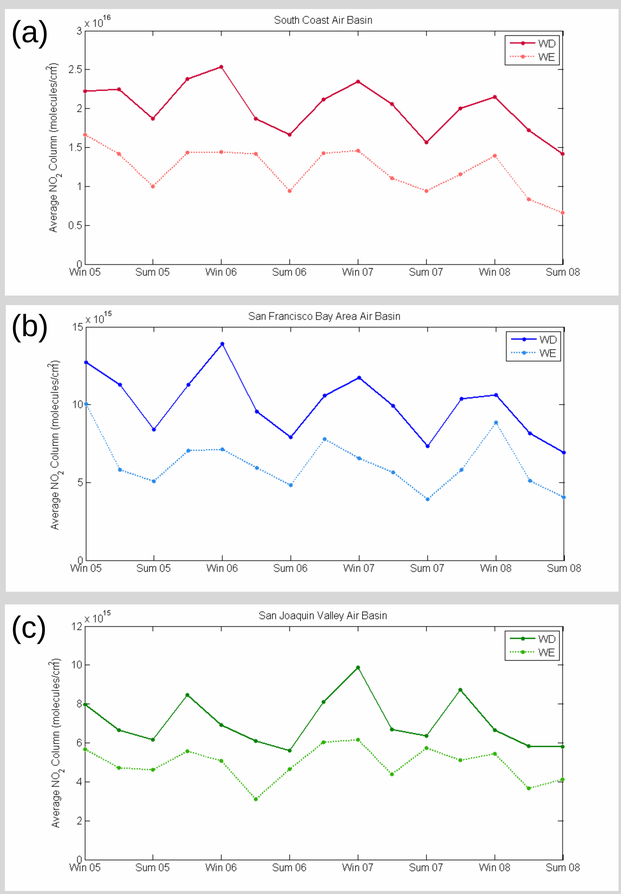

Figure 6. Average tropospheric NO_2 column concentrations (molecules/cm^2) from OMI for weekdays (solid) and weekends (dashed) for (a) the South Coast, (b) the San Francisco Bay Area, and (c) the San Joaquin Valley regions of California as defined by Figures 1-3. Higher concentrations in winter relative to summer reflect the seasonal variation in NO_x lifetime. Looking only at summers, when NO_x lifetime is short and observations provide the most accurate reflection of emissions, we find similar decreases in weekday and weekend concentrations in each of the basins of approximately 1E15 molecules/cm^2 per year in the South Coast, 5E14 molecules/cm^2 per year in the San Francisco Bay Area, and 3E13 molecules/cm^2 per year in the San Joaquin Valley.

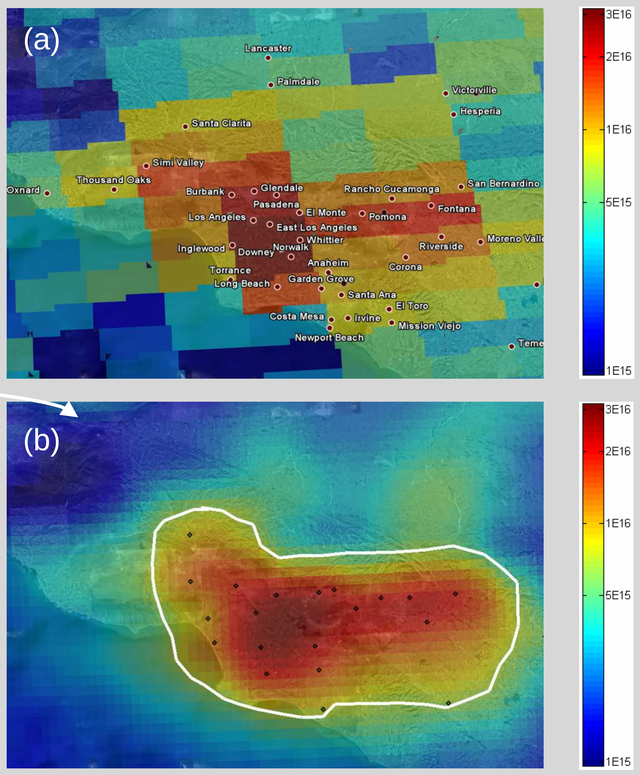

Figure 3. (a) Tropospheric column NO_2 concentrations (molecules/cm^2) from the Ozone Monitoring Instrument (OMI) over the South Coast region of California from one day, August 1, 2008. The satellite's 16 day repeat pattern provides daily measurements at different spatial resolutions which allows regridding of NO_2 columns using an area-weighted average. In (b) we show OMI NO_2 columns averaged over summer months (Jun-Aug) for the years 2005-2008 at 0.04 degree resolution. White outline and black diamonds in (b) as in Figure 1.

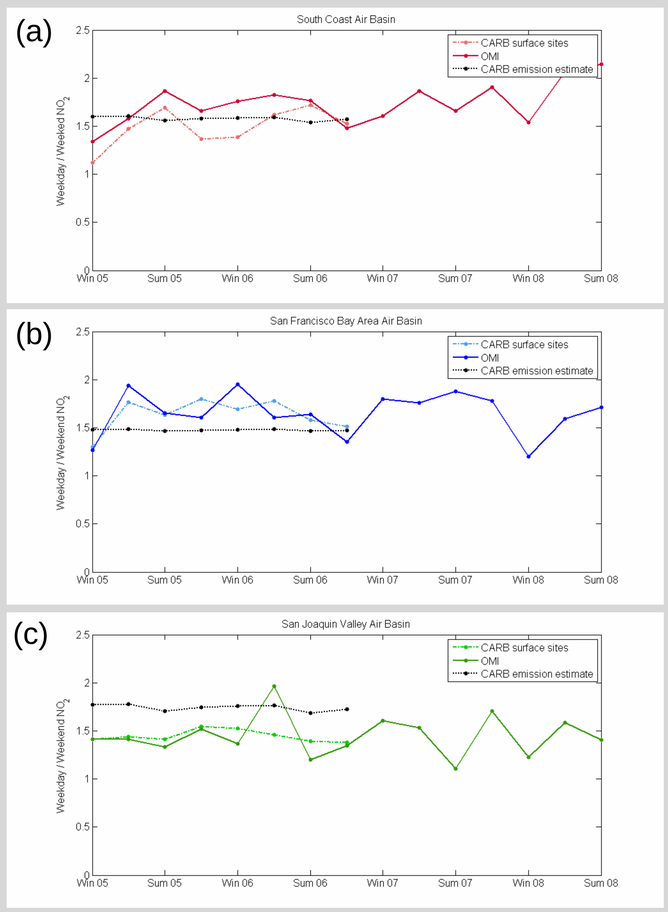

Figure 7. The ratio of weekday to weekend NO_2 concentrations from OMI (tropospheric column concentrations), the California Air Resources Board (CARB) monitoring sites, and CARB emission estimates for (a) the South Coast, (b) the San Francisco Bay Area, and (c) the San Joaquin Valley regions of California as defined by Figures 1-3. Estimated day-of-week activity patterns for on-road (Chinken et. al, 2002) and off-road (Janssen et. al, 1999) sources were used to account for day of week variation in emissions estimates. As in Figure 6, we focus on summers and find that the ratio of weekday to weekend emissions is increasing with a slope of 0.07 in the South Coast, 0.04 in the San Francisco Bay, and 0.01 in the San Joaquin Valley. These positive slopes reflect the increasing relative importance of weekday emissions when diesel contributions are maximized. CARB emissions estimates show good agreement in the South Coast basin but are low in the San Francisco Bay and high in the San Joaquin Valley when compared with satellite and surface measurements.

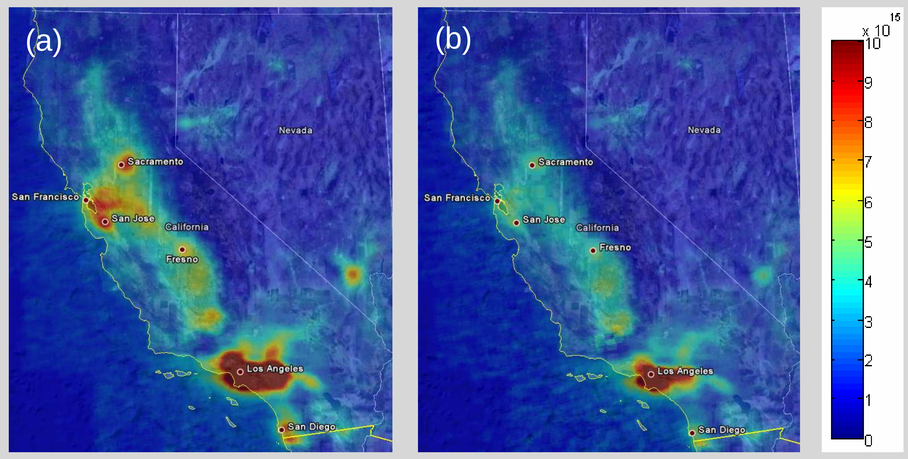

Figure 4. Average OMI tropospheric NO_2 column concentrations (molecules/cm^2) for (a) weekdays (Tuesday-Friday) and (b) weekends (Saturday-Sunday) for Jun-Aug 2005-2008.

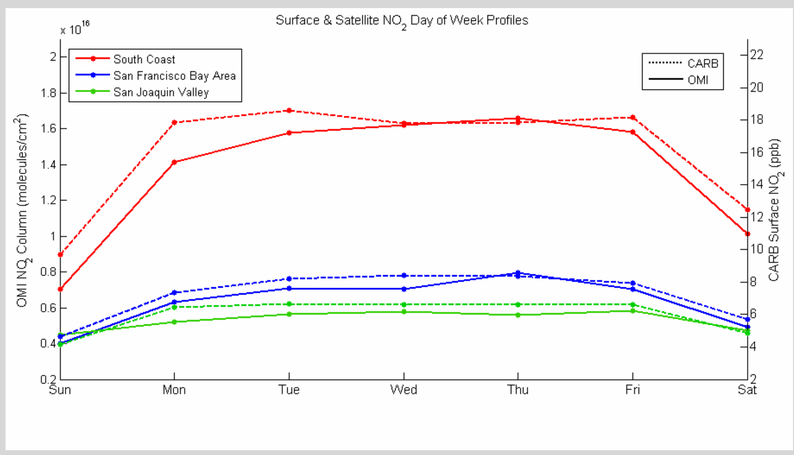

Figure 5. Average day of week tropospheric NO_2 profiles from OMI (solid) and CARB monitoring sites (dashed) for summer (Jun-Aug) 2004-2007 in the South Coast, San Francisco Bay Area, and San Joaquin Valley regions of California as defined by the outlines in Figures 1-3.

Conclusions

1) The high precision of OMI allows accurate measures of day of week variation on a regional scale.

2) Day of week profiles from OMI and CARB surface measurement sites agree well indicating that the OMI NO_2 tropospheric column is representative of NO_x concentrations at the surface.

3) Trends in NO_2 column concentrations from OMI show an increase in the relative importance of weekday diesel emissions.

4) OMI NO_2 column concentrations offer an unambiguous test of the accuracy of emission inventories.

References

1) Janssen et. al, (1999) Weekday and weekend day temporal allocation of activity in the NONROAD model. Report prepared for the U.S. Environmental Protection Agency, Office of Mobile Sources by Nonroad Engine Emission Modeling Team, NR-015. March.

2) Chinkin et. al, (2002) Weekend/weekday ozone observations in the South Coast Air Basin Volume III: Analysis of summer 2000 field measurements and supporting data. Final report prepared for the National Renewable Energy Laboratory, Golden, CO by Sonoma Technology, Inc., Petaluma, CA, STI-999670-2124-FR, April.

Acknowledgements

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